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17

The effect of humans on the cognitive development of apes

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Homo sapiens is the only animal species whose ontogeny normally takes place in an environment containing both artifacts designed to assist and enhance cognition and adult conspecifics eager to demonstrate and instruct the individual in all kinds of cognitive activities including the use of artifacts. *Homo sapiens* is also the only animal species to acquire during its ontogeny certain cognitive skills, for example skills associated with complex object manipulations and language. Perhaps this is not an accident. Perhaps the presence of a cultural environment, complete with material and symbolic artifacts and adult instruction, is an essential ingredient in the cognitive development of *Homo sapiens* (Vygotsky, 1978).

In this chapter we explore the possibility that the human cultural environment is also an important ingredient in the cognitive development of some nonhuman individuals, specifically some individual great apes (hereafter, simply "apes"). It is quite common in studies of ape cognitive development for observers to note marked individual differences in the cognitive skills of particular apes – sometimes within studies but also across different studies of the same phenomenon. Whereas there are undoubtedly many factors responsible for these differences, one factor may be the degree to which, or the manner in which, particular individuals have been in contact with the human cultural environment. Indeed, most primatologists would probably not be surprised to find different cognitive skills among adult apes who have spent their ontogenies in species typical environments, in human zoos, in human laboratories where they have been taught specific skills, in human-staffed nurseries, and in human homes where they have been treated as if they were human children. But precisely what are the effects of these different environments is very much an open question. Opinions range from those of Boesch (1993), who has argued that apes display their most sophisticated cognitive skills in the natural conditions in which their evolution has taken place and that captive conditions, however rich, only diminish or distort those abilities, to those of Premack (1983), who has argued that when apes are raised with all of the education and training received by human children,

especially in the use of symbols, they display a set of abstract cognitive skills that they show under no other conditions.

The major problem in attempting to review evidence related to this issue is that humans may intervene in the lives of apes in many and varied ways that do not always fall neatly into categories. In addition, there are many ape individuals who have spent different parts of their lives in different settings. To make matters even more complex, in many published reports scientists do not report, or report only briefly, on the histories of the individuals being studied. Although there is no perfect solution to these problems, for the purposes of this review, we will use the following very general descriptive terms, but will qualify them with more explicit detail when necessary:

WILD. Apes who have spent their entire lives in their natural habitats.

CAPTIVE. Apes in human captivity who have interacted directly with humans and their artifacts only minimally; this includes many zoo and some laboratory settings.

NURSERY-RAISED. Apes raised from a young age with peer conspecifics and a good deal of contact with humans and their artifacts, but without human training aimed at specific behavioral outcomes.

LABORATORY-TRAINED. Apes raised mostly in human captivity who have been trained in particular tasks, sometimes multiple tasks over many years (some of which might be symbolic).

HOME-RAISED. Apes raised by humans in something like a human cultural environment (sometimes including exposure to or training in symbolic skills); the environment need not literally be a home but must include something close to daily contact with humans and their artifacts in meaningful interactions.

Our goal in this review is to determine as specifically as possible the nature of the effects these different human environments may have on the cognitive development of the four great ape species: chimpanzees (*Pan troglodytes*), bonobos (*Pan paniscus*), orangutans (*Pongo pygmaeus*), and gorillas (*Gorilla gorilla*). We are interested in apes' knowledge both of objects and their causal and logicomathematical relations and of other animate beings and how they operate in the world. After reviewing the available data in each of these broad domains of cognition, we conclude by identifying four very specific mechanisms of human influence that may affect the cognitive development of our nearest primate relatives.

KNOWLEDGE OF OBJECTS

In this section we investigate whether and in what ways apes come to interact with objects in more complex or human-like ways as a function of their social experience with humans. We approach this issue in subsections dealing with each of the major domains in which ape physical cognition has been studied: object permanence, object manipulation, tool use, and categorization. Table 17.1 lists the studies we rely on for this analysis, classifying each of the studies used in terms of the cognitive domain involved and the category of human contact its subjects experienced.

Object permanence

Existing data on the object permanence skills of apes provide little evidence for the significance of rearing environment. Apes seem to have a basic knowledge of the existence and location of objects when the latter are out of sight, whether they are foraging for food in their natural environments (Boesch & Boesch, 1984) or whether they are tracking the invisible displacements of objects in the laboratory. Although Piagetian tasks have not been given to apes in the wild, of course, in the laboratory any number of chimpanzees and gorillas who have had many different types of experience with humans, some very limited, have solved all of the object permanence problems presented to them, including stage 6 invisible displacements. In the one study in which individuals with different backgrounds were explicitly compared on object permanence tasks (Hallock & Worobey, 1984; Table 17.1), a small developmental advantage was found for nursery-reared over captive chimpanzees in the age of emergence of basic search skills. These subjects, however, were not followed longitudinally to assess their final attainments.

Object manipulation

In their natural habitats the four great ape species engage in object manipulation mostly in the context of instrumental situations involving food and nesting materials. These can sometimes be quite complex (see Chapter 5), but there does not seem to be a human-like motivation to manipulate objects as an end in itself. When they have been raised with humans and their artifacts, however, apes seem to become more interested in objects solely as objects. For example, Gómez (1989) found that a nursery-raised gorilla exposed to extensive human interaction on a daily basis, often in concert with human objects, displayed a number of complex object manipulations, including object construction, not typically displayed by gorillas with less human contact – although it should be noted that Gómez's subject was tested at an age slightly older than that of the other gorillas (4 versus 3 years of age). Similarly, a home-raised orangutan exposed to extensive human interaction (Miles, 1990), as well as some rehabilitant orangutans raised by humans (Russon & Galdikas, 1993), have been observed to display object construction skills and human-conventional manipulations not typically observed in orangutans with less human contact (Chevalier-Skolnikoff, 1983; Laidler, 1980). And finally, complex object constructions and conventional manipulations have also been observed in chimpanzees and bonobos that have had extensive contact with humans (e.g. K.E. Brakke & E.S. Savage-Rumbaugh, unpublished results; Hayes & Hayes, 1951), whereas they have been reported for nursery-raised chimpanzees only infrequently and not until the juvenile period.

Symbolic play

A special type of object manipulation is symbolic or pretend play. Symbolic play is very difficult to identify precisely, especially when human artifacts are not involved. For example, Goodall (1986) reported that a young chimpanzee "fished" for ants with a twig at a place where no ants were present – raising the possibility that the chimpanzee was imagining the presence of ants – but many other interpretations of this behavior are also

Table 17.1. *Studies relevant to ape knowledge of objects as a function of domain of knowledge and rearing history of subjects*

	Wild	Captive	Nursery-raised	Laboratory-trained	Home-raised	Other
Object permanence	Boesch & Boesch, 1984; Goodall, 1986 Ages: various	Hallock & Worobey, 1984 Ages: i	Hallock & Worobey, 1984; Mathieu & Bergeron, 1981; Natale *et al.*, 1986; Redshaw, 1978; Spinozzi & Poti, 1993 Ages: i, I, J		Wood *et al.*, 1980 Ages: I	
Object manipulation	Byrne & Byrne, 1993; McGrew, 1977 Ages: various	Chevalier-Skolnikoff, 1983; Vauclair & Bard, 1983 Ages: i, I, J, S	Chevalier-Skolnikoff, 1983; *Gómez, 1989*; Jacobsen *et al.*, 1932; Knobloch & Pasamanick, 1959; Laidler, 1980; *Mignault, 1985*; Perinat & Dalmau, 1988; Redshaw, 1978; Spinozzi & Natale, 1989 Ages: i, I, J		K.E. Brakke & E.S. Savage-Rumbaugh, unpublished results; Hayes & Hayes, 1951; Kellogg & Kellogg, 1933; Miles, 1990; Vauclair & Bard, 1983 Ages: i, I, J	Galdikas, 1982; Russon & Galdikas, 1993 Ages: I, J, S, A
Symbolic play	Goodall, 1986 Ages: I	Wimmer & Ettlinger, 1977 (cited in Ettlinger, 1983) Ages: I	*Mignault, 1985* Ages: I, J	Savage-Rumbaugh, 1986 Ages: J	Gardner & Gardner, 1978, 1989; Hayes, 1951; Jensvold & Fouts, 1993; Miles, 1990; Patterson & Linden, 1981; Savage-Rumbaugh & McDonald, 1988 Ages: I, J, S, A	
Tool use	Boesch & Boesch, 1990; Goodall, 1986; McGrew, 1989, 1992 Ages: I, J, S, A	Chevalier-Skolnikoff, 1983; Jordan, 1982; Köhler, 1927; Lethmate, 1982; Menzel, 1972; Menzel *et al.*, 1970; Parker, 1969; Savage & Snowdon, 1982; Schiller, 1952; Visalberghi *et al.*, 1995; Yerkes, 1927 Ages: I, J, S, A	K.A. Bard, D.M. Fragaszy & E. Visalberghi, 1993; Chevalier-Skolnikoff, 1983; Natale, 1989a,b; Spinozzi & Natale, 1989 Ages: i, I, J, S, A	Limongelli *et al.*, 1995; Visalberghi *et al.*, 1995 Ages: J, S, A	Hayes & Nissen, 1971; Miles, 1990; Patterson, 1978; Savage-Rumbaugh, 1986; Visalberghi *et al.*, 1995 Ages: I, J, S, A	Galdikas, 1982; Menzel *et al.*, 1970; Rijksen, 1978; Russon & Galdikas, 1993 Ages: I, J, S, A
Use of mirrors		Gallup, 1970; Gallup *et al.*, 1971; Hyatt & Hopkins, 1994; Lethmate & Dücker, 1973; Povinelli *et al.*, 1993; Riopelle *et al.*, 1973; Suarez & Gallup, 1981; Swartz & Evans, 1991, 1994 Ages: I, J, S, A	Lin *et al.*, 1991; Povinelli *et al.*, 1993; Suarez & Gallup, 1981 Ages: I, J, S, A	Savage-Rumbaugh, 1986; Swartz & Evans, 1994 Ages: J, A	Hayes, 1951; W.D. Hopkins, personal communication; Miles, 1994; Patterson & Cohn, 1994 Ages: I, J, A	Gallup *et al.*, 1971; Hill *et al.*, 1970 Ages: J
Categorization	Boesch & Boesch, 1990 Ages: various	Garcha & Ettlinger, 1979; Oden *et al.*, 1990; Rensch, 1973 Ages: i, I, J	*Braggio et al., 1979; Mathieu, 1982*; Savage-Rumbaugh *et al.*, 1992; Spinozzi, 1993 Ages: i, I, J, A	Matsuzawa, 1990; Premack, 1983; Yerkes & Petrunkevitch, 1925 Ages: J, S, A	Hayes & Nissen, 1971; Miles, 1990; Patterson & Linden, 1981; Savage-Rumbaugh, 1986; Savage-Rumbaugh *et al.*, 1992 Ages: I, J, S	
Numerical skills				Boysen & Bernston, 1990; Matsuzawa, 1990; Rumbaugh *et al.*, 1989 Ages: J, S, A		

i, young infant (0–1 year old); I, old infant (1–3 year old); J, juvenile (3–7 year old); S, subadult (7–12 year old); A, adult (12 year old or older); *italic* references, additional human contact.

possible. Observations of captive apes have not revealed many candidates for pretense either, even when human artifacts are present. For example, Mignault (1985) reported that, with the exception of some limited manipulation of dolls, symbolic play was not observed in four nursery-reared juvenile chimpanzees who had received regular exposure to humans and a variety of toys (see also Wimmer & Ettlinger, 1977, cited in Ettlinger, 1983). Observations of home-raised apes have provided by far the widest variety of possible instances of symbolic play. All four ape species have been observed to play with dolls, engaging in a number of different activities including such things as bathing, feeding, and tickling. Patterson & Linden (1981) reported that the home-raised gorilla Koko pretended to be an elephant by using a fat rubber tube as a substitute for the trunk; Hayes (1951) reported that the home-raised chimpanzee Viki played with a nonexistent pull toy; and the home-raised bonobo Kanzi was observed to engage others in an eating game involving imaginary food (Savage-Rumbaugh & McDonald, 1988). On the other hand, Miles (1990) reported that symbolic play was not observed in her home-raised orangutan Chantek. It is unclear in all of these cases what these behaviors meant for these individuals, and in many cases they may have been simply playing with objects that humans see as symbolic (e.g. dolls), or else mimicking a past act of human pretense. Nevertheless, it still seems important that the only serious candidates for symbolic play are all provided by home-raised apes.

Tool use

Of the four great ape species, only chimpanzees use tools on a regular basis in their natural habitats (McGrew, 1989). Chimpanzees use, and in some cases modify, more than a dozen different kinds of object as tools to solve problems, most of them having to do with the acquisition of food (McGrew, 1992). Given chimpanzees' extensive use of tools in the wild, it is not surprising that in captivity they use tools extensively as well. Chimpanzees deprived of experience with either conspecifics or objects do not use tools efficiently, although this deficiency can be reversed with experience (Menzel *et al.*, 1970; Schiller, 1952). Orangutans, bonobos, and gorillas show a different and very interesting pattern of tool use. Gorillas and orangutans with very little human contact use various human-like tools in a variety of problem-solving situations (see Table 17.1). Rehabilitant orangutans – raised with various types of human contact – also display a rich variety of tool-using skills (Russon & Galdikas, 1993), and there is some evidence that captive bonobos have some of these skills as well (Jordan, 1982). Home-raised orangutans, gorillas, and bonobos have also learned to use a wide variety of human tools. There are no studies that directly compare the tool use performance of apes with different rearing backgrounds, but Visalberghi and colleagues have recently completed a series of studies (see Table 17.1) in which the performance of chimpanzees and bonobos with different rearing histories can be compared, and they found that different amounts of experience with humans was not associated with different levels of proficiency in their tool use task.

Use of mirrors

Apes have also been observed and tested in their ability to use a somewhat special human tool, the mirror (Gallup, 1970). Of interest are self-directed behaviors, in which individuals use a mirror to explore body parts that would not otherwise be visually accessible, including especially self-directed behaviors in the so-called mark test in which subjects seek to remove a painted spot that has been surreptitiously placed on a visually inaccessible part of their face. For obvious reasons, apes in the wild have not been systematically observed in interaction with mirrors, and so we do not know how they might use them. However, numerous studies have found that individuals of all four ape species with very limited human contact display self-directed behaviors and pass the mark test (see Captive column in Table 17.1). Subjects raised with extensive human contact – several chimpanzees, one bonobo, two gorillas, and one orangutan – have displayed these behaviors as well. Interestingly, two studies that investigated socially-deprived chimpanzees (deprived of both conspecific and human contact) found that they uniformly failed the mark test (Gallup *et al.*, 1971), although this effect can be reversed with later social contact with conspecifics (Hill *et al.*, 1970). It is thus conceivable that socialization plays an important role in the development of self-recognition in chimpanzees, but not necessarily human socialization.

The conclusion would thus seem to be that rearing environment has a definite effect on the tool-using skills of apes, as three of four species use tools extensively only in captivity. The effect does not seem to be a profound one, however, since simple exposure to situations in which tools might be useful is enough to elicit tool use. Ape use of mirrors to perform self-directed behaviors does not seem to be affected to any significant degree by the amount of human contact. Because socially deprived chimpanzees have failed the mark test, it is possible that social interaction in general, though not necessarily of the human kind, is important to the development of this skill.

Categorization

If categorization is defined as the sorting of objects into distinct spatial groupings on the basis of their perceptual or functional features, then there are only a few instances of ape categorization in the wild. However, apes do a number of things in their natural environments that indicate a kind of categorization, for example the gathering together of particular types of food item (e.g. nuts for cracking, plants ripe for eating, etc.), or materials for making tools (Boesch & Boesch, 1990). Wild apes thus clearly show some natural categorization abilities in a number of different functional contexts.

When placed in front of human objects, captive chimpanzees do not spontaneously sort them into groups on the basis of their perceptual or functional features (Garcha & Ettlinger, 1979; Mathieu, 1982), nor do bonobos (Savage-Rumbaugh *et al.*, 1992). They may, however, interact with them in an order that implies a recognition of common features, for example by touching *seriatim* all of the objects with a certain shape (Rensch, 1973; Spinozzi, 1993). Home-raised apes and laboratory-trained apes, however, often do sort objects into distinct groups; for example, Matsuzawa (1990) found several cases of spontaneous sorting in a laboratory-trained, language-trained chimpanzee. Spontaneous classification of different items according to certain morphological features such as material, color, shape, or size has also been reported in one home-raised chimpanzee (Hayes & Nissen, 1971) and one home-raised bonobo (Savage-Rumbaugh, 1986).

With regard to the other two ape species, a home-raised gorilla (Patterson & Linden, 1981) and a home-raised orangutan (Miles, 1990) have also been reported to display categorization skills. It is relevant here that chimpanzee subjects who do not spontaneously classify objects can in many cases be taught to do so (Garcha & Ettlinger, 1979), although perhaps not with the skill of the human-raised ape of Hayes & Nissen (1971).

Premack (1983) found that only laboratory-trained, language-trained chimpanzees were capable of solving analogies (i.e. categorizing the relations of pairs of stimuli) in a match-to-sample procedure; captive chimpanzees failed these tasks despite extensive training. Premack (1983) originally interpreted these results as evidence for the necessity of an abstract code (i.e. language) to develop complex relational categories. More recently, however, Oden *et al.* (1990) found that very young captive infant chimpanzees spontaneously perceived relations between relations of stimuli (i.e. analogies between pairs of stimuli) when this was measured more generously, i.e. when experimenters simply noted the time individuals played with objects related to one another in different ways (a finding consistent with the studies on serial touching of Rensch (1973) and Spinozzi (1993)). The revised conclusion is thus that the presence of an abstract code is not necessary for the perception of relations of same/different between objects and between pairs of objects (i.e. natural categorization), but it might still be the case that using this perceptual ability to physically group objects (i.e. classification) may require some additional attention-management skills in which humans play a role.

Numerical skills

An important set of behaviors related to categorization skills comprises the numerical skills of chimpanzees. In this case, the only way of testing individuals is by giving them laboratory training in how to respond in the presence of particular types of stimuli. Research reported by Rumbaugh *et al.* (1989), Matsusawa (1990), Boysen & Bernston (1990), and Boysen (Chapter 8) show that laboratory-trained chimpanzees display a variety of numerical skills involving the comparing of quantities, the use of Arabic numerals, and so forth. It is interesting to note, however, that monkeys with little human contact show very rudimentary numerical skills in the form of subitizing (perceptual discrimination of different numerosities; Thomas, 1992).

Overall, then, rearing environment does seem to have some effect on apes' categorization and classification skills. Apes with extensive human contact show more human-like classificatory skills in physically sorting objects into groups than nursery-raised or other captive apes. However, in other tasks related to natural categorization skills – e.g. touching similar objects serially or perceiving categories as measured by manipulative time – captive apes perform at the same level as human-raised apes. It is thus likely that all apes have some skills of natural categorization at the perceptual level, but that explicit classification on a more conceptual level (coordinating similarities and differences simultaneously and systematically) requires some additional attention-management skills and that these might develop only in the context of human instruction.

SOCIAL KNOWLEDGE

A number of scientists have argued that the cognitive capacities of primates are most naturally deployed when they are attempting to solve social, not physical problems (e.g. Humphrey, 1976; Jolly, 1966). In their natural environments apes must cooperate and compete with conspecifics over access to resources, communicating with and learning from them in the process (de Waal, 1982). In this section we review existing data for the effect of humans on the development of ape social cognition in subsections dealing with each of the major domains in which it has been studied: social attention, intentional communication, social learning, cooperation, and "theory of mind." Table 17.2 lists the studies we rely on for this analysis, classifying each of the studies used in terms of the socio-cognitive domain involved and the category of human contact its subjects experienced.

Social attention

Using the Neonatal Behavioral Assessment Scale, Hallock *et al.* (1989) found that two human-reared chimpanzees were more responsive in their orientation to social stimuli (e.g. vocalizations) than were seven mother-reared conspecifics. Bard *et al.* (1992) compared 13 nursery-raised chimpanzee neonates to Hallock *et al.*'s seven mother-reared chimpanzees and also found significant differences in attention to human stimuli.

Social referencing

Social referencing is a form of social attention in which an individual actively monitors the reaction of another individual to some outside entity or event and then uses information about this reaction in formulating its own response to that entity or event. There is no question that all four great ape species in their natural environments are affected in some generic way by the behaviors and emotional reactions of groupmates; when a fearful or exciting event is occurring fear and excitement seem to "spread" among individuals (Sugiyama, 1972). With regard to captive apes, Evans & Tomasello (1986) observed that the infant and juvenile chimpanzees of a captive colony interacted more frequently with their mothers' preferred social partners than with other adults (irrespective of mothers' physical distance), raising the possibility of social referencing. Menzel *et al.* (1972) provoked fearful or cautious responses to two novel objects in some young captive and isolate chimpanzees and then watched this spread to other chimpanzees as they added them to the group. Miller *et al.* (1990) introduced nursery-reared infant chimpanzees to a novel, potentially frightening human in the presence of a familiar human care, and 2 year old males (as opposed to other subjects) increased their looking time to the caregiver when compared to baseline levels. With regard to home-raised chimpanzees, Kellogg & Kellogg (1933) and Hayes (1951) observed that their home-raised chimpanzees looked to them in many situations where they were frightened or uncertain (for the same phenomenon in laboratory-trained chimpanzees, see Savage-Rumbaugh *et al.*, 1983).

Joint attention

Joint attention is similar to social referencing – they are both triadic interactions involving two individuals and some outside entity – but it mainly concerns the visual

Table 17.2. *Studies relevant to ape social knowledge as a function of domain of knowledge and rearing history of subjects*

	Wild	Captive	Nursery-raised	Laboratory-trained	Home-raised	Other
Social attention		Hallock *et al.*, 1989 Ages: i	Bard, 1992a; Bard *et al.*, 1992; Hallock *et al.*, 1989 Ages: i			
Social referencing	Sugiyama, 1972 Ages: I	Evans & Tomasello, 1986; Menzel *et al.*, 1972 Ages: I, J	Miller *et al.*, 1990 Ages: I, J	Savage-Rumbaugh *et al.*, 1983 Ages: J	Hayes, 1951; Kellogg & Kellogg, 1933 Ages: i, I, J	Menzel *et al.*, 1972 Ages: I, J
Joint attention	Plooij, 1978 Ages: I, J	Bard & Vauclair, 1984; *Carpenter et al., 1995*; de Waal, 1986; Menzel, 1971, 1973a Ages: i, I, J, S, A	Bard & Vauclair, 1984 Ages: i		Bard & Vauclair, 1984; Carpenter *et al.*, 1995; Hayes, 1951 Ages: i, I, J, S, A	
Intentional communication	Boesch, 1991a; Galdikas & Vasey, 1992; Goodall, 1986; Hauser, 1990; McGinnis, 1979; Plooij, 1978 Ages: I, J, S, A	*Carpenter et al., 1995*; de Waal & van Hooff, 1981; *Savage-Rumbaugh, 1984*; Tomasello *et al.*, 1985, 1989, 1994; Yerkes & Nissen, 1939 Ages: I, J, S, A	Berdecio & Nash, 1981; Call & Tomasello, 1994a; *Gómez, 1989, 1990* Ages: I, J, S	Povinelli *et al.*, 1992; Premack, 1988; Savage-Rumbaugh *et al.*, 1983; Woodruff & Premack, 1979 Ages: J, S, A	*Call & Tomasello, 1994a; Carpenter et al.*, 1995; Gardner & Gardner, 1989; Miles, 1986, 1990; Patterson, 1978; Patterson & Linden, 1981; Savage-Rumbaugh, 1986, 1988; Savage-Rumbaugh & McDonald, 1988; Savage-Rumbaugh, *et al.*, 1985, 1986 Ages: I, J, S, A	Bard, 1992b Ages: I, J
Social learning	Boesch, 1992; Goodall, 1986, 1990; McGrew & Tutin, 1978; Nishida, 1980 Ages: various	Call & Tomasello, 1994b; de Waal, 1982; Ettlinger, 1983; Haggerty, 1913; Nagell *et al.*, 1993; Tomasello *et al.*, 1987; Wright, 1972; Yerkes, 1927 Ages: J, S, A	K.A. Bard, D.M. Fragaszy & E. Visalberghi, unpublished results; Call & Tomasello, 1994b; Custance & Bard, 1994; Gómez, 1989; *Mathieu, 1982*; Nagell *et al.*, 1993; Perinat & Dalmau, 1988; *Tomasello et al., 1987, 1993b* Ages: I, J, S, A		Fouts, 1972; Fouts *et al.*, 1989; Gardner & Gardner, 1978; Hayes, 1951; Hayes & Hayes, 1952; Miles, 1990; Miles *et al.* (Chapter 13); Patterson, 1978; Sanders, 1985; Savage-Rumbaugh *et al.*, 1986, 1992; Temerlin, 1975; Terrace, 1979; Tomasello *et al.*, 1993b Ages: I, J, S, A	Galdikas, 1982; Russon & Galdikas, 1993 Ages: I, J, S, A
Teaching	Boesch, 1991b; Goodall, 1986; van Lawick-Goodall, 1968; van de Rijt-Plooij & Plooij, 1987 Ages: A	K.A. Bard, unpublished results; Crawford, 1937; *Savage-Rumbaugh, 1984*; Yerkes & Tomilin, 1935 Ages: A			Fouts *et al.*, 1982; Patterson & Linden, 1981 Ages: J, A	
Cooperation	Boesch & Boesch, 1989; Nishida, 1979; Teleki, 1973 Ages: A	Chalmeau, 1994; Crawford, 1937, 1941; de Waal, 1982; Köhler, 1927; Menzel, 1972, 1973b Ages: I, J, S, A		Povinelli *et al.*, 1992; Savage-Rumbaugh *et al.*, 1978a Ages: J, S, A	Hayes, 1951; Savage-Rumbaugh *et al.*, 1986; Terrace, 1979 Ages: I, J	
Theory of mind		de Waal, 1982; Savage-Rumbaugh, 1984; Tanner & Byrne, 1993; Tomasello *et al.*, 1994 Ages: I, J, S, A	Call & Tomasello, 1994a; Fernández & Gómez, 1983; D.J. Povinelli & H.K. Perilloux, unpublished results; Povinelli *et al.*, 1994 Ages: I, J, S	Povinelli *et al.*, 1990; Premack, 1986,1988; Premack & Woodruff, 1978 Ages: S, A	Call & Tomasello, 1994a; Miles, 1990; Tomasello *et al.*, 1993b Ages: J, S, A	

i, young infant (0–1 year old); I, old infant (1–3 year old); J, juvenile (3–7 year old); S, subadult (7–12 year old); A, adult (12 year old or older); *italic* references, additional human contact.

attention of others rather than their emotional reactions. Chimpanzees in the wild have been observed on many occasions to follow the gaze of others (Plooij, 1978). De Waal (1986) reported that a captive male vocalized loudly and looked to a particular location on several occasions, seemingly to attract the attention of other group members to that location (see also Menzel, 1971, 1973a). With regard to home-raised chimpanzees, Hayes (1951) observed the effectiveness of focusing her attention on a particular place to make the home-raised chimpanzee Viki approach and inspect the same place. The two studies that have explicitly compared ape joint attention as a function of human experience have found some differences as a function of rearing history. Bard & Vauclair (1984) found that a nursery-reared chimpanzee attended and responded appropriately to human attempts to engage him in object manipulation in a way that a captive chimpanzee and home-raised bonobo did not – although all subjects were too young to engage in extensive object manipulation. Along these same lines, Carpenter *et al.* (1995) found that home-raised bonobos and chimpanzees engaged more frequently in relatively long episodes of joint attention with humans and attended to the human's actions on objects to a greater extent than did captive conspecifics (who were slightly, though not significantly, younger in age).

In general, then, apes are socially attentive to others and their feelings and visual attention, with or without human contact. There do seem to be some minor quantitative increases in these behaviors with increasing human contact, but it is not likely that these are of great significance.

Intentional communication

In contrast to social attention processes, in which one individual follows into another's attention or behavior, intentional communication concerns an individual's attempts to get others to follow into its attention or behavior. According to Bates (1976) there are two basic functions of intentional communication. On the one hand, an individual may use a communicative signal to get another individual to help in attaining a goal; these are called imperatives. On the other hand, an individual may draw another's attention to something in the environment merely for the sake of sharing attention to it (e.g. by holding it up and showing it); these are called declaratives.

The use of imperatives is by far the most common form of intentional communication that has been observed in apes. For example, in a captive chimpanzee colony Tomasello and colleagues have observed requests for nursing, grooming, food, play, and travel (e.g. Tomasello *et al.*, 1985, 1989, 1994). Gestures in most of these categories are seen in the wild as well. Bard (1992b) observed a number of imperative gestures in both juvenile rehabilitant and wild orangutans. Other more complex kinds of imperative are seen only in apes with more extensive human contact, e.g. dragging a human by the arm to a location where he or she might provide some assistance (e.g. the nursery gorilla with extra human contact described by Gómez (1989, 1990)), or giving a nut to a person who was supposed to crack it open, even slapping the nut and placing a stone on top of it to indicate what should be done (e.g. the home-raised bonobo described by Savage-Rumbaugh

et al. (1986)). Apes with human contact are also the only apes to produce imperative pointing. Pointing is learned rather easily by apes in human interaction, either in the context of specific experiments (Povinelli *et al.*, 1992; Woodruff & Premack, 1979) or in a more "natural" way in home-raised apes who often use pointing to request objects or indicate locations to which they wish to travel (e.g. Miles, 1990; Savage-Rumbaugh *et al.*, 1986). In terms of the comprehension of imperative pointing, apes with extensive human contact are also the only apes to show human-like skills. Yerkes & Nissen (1939) reported that their captive chimpanzees did not comprehend human pointing, and Savage-Rumbaugh (1984) observed that a captive adult bonobo ignored the pointing of her home-raised offspring who had learned to point for humans. In contrast, Woodruff & Premack (1979) and Povinelli *et al.* (1992) reported that laboratory-trained chimpanzees comprehended human pointing with very little training. Call & Tomasello (1994) compared the performance of two orangutans with different histories of human contact and found that only the home-raised orangutan comprehended human pointing.

The use of declarative gestures is much less frequent in apes, and may be confined to apes with extensive human contact. Plooij (1978) observed that wild chimpanzee infants used objects to get the attention of social partners, but this behavior was not a declarative as it was used as a way of getting the other to begin travel. Tomasello *et al.* (1994) observed a number of these types of gestures in captive chimpanzees as well (e.g. holding out a stick to another, and then clutching it to the chest, as a way of initiating play). However, the function of the gesture in these cases is to attract attention to the self, or to initiate play with the self, not to share attention to the object as in prototypical declaratives such as "showing." However, there are some reports of declarative gestures in home-raised apes, although in all cases interpretation is an issue. Possible instances of "showing" in home-raised gorillas, chimpanzees, and bonobos have been reported by Patterson (1978), Savage-Rumbaugh (1988) and Savage-Rumbaugh *et al.*, (1985). Carpenter *et al.* (1995) also observed two instances of what seemed to be the showing of objects to humans by a bonobo. It should be noted, however, that some of the subjects that use declaratives have been trained to perform them (Savage-Rumbaugh *et al.*, 1983), and thus there is some question about their underlying motivation. It is also noteworthy that home-raised apes also sometimes use their symbols for commenting on current activities, anticipating a future action, or commenting on past events (Savage-Rumbaugh *et al.*, 1985), although it is possible in these cases that the subjects are simply associating their signs with specific stimuli.

Another phenomenon of intentional communication is deception. Many anecdotal instances of deception have been reported for the four great apes in a variety of environments (Byrne & Whiten, 1990). These involve both the suppression of communicative behavior that would be produced under normal circumstances and the conveying of false information. Whether these are instances of deception requiring some sort of social cognition, however, or whether they are procedures for effecting desired outcomes, is still an open question. The best evidence is the experimental study of Woodruff & Premack (1979) in which chimpanzees, with varied backgrounds of association with humans, learned to suppress information such as body orientation or glances to a

baited container when a competitive trainer who would not share food was present; they used all of these when a cooperative trainer was present. Some subjects also reliably misdirected the competitive trainer. It is important to point out that in this study it took subjects more than 20 trials to begin to differentiate between the two types of trainer, however, and thus they might have learned during the course of these early trials what the most effective procedures might be.

In summary, imperatives are by far the dominant form of communication for apes across all rearing conditions. The number and sophistication of imperatives increases with human contact. Activities such as placing the other's hand on the object to be manipulated, demonstrating actions, and pointing only appear in apes with human contact, and only home-raised or laboratory-trained apes seem to comprehend human pointing. The only clear instances of prototypical declarative gestures, in which the only motivation seemed to be to share attention to an object with another, have been produced by home-raised apes – both in their natural behavior and in their use of human-like symbols. Communicative signals and symbols used for deceptive purposes have been reported for apes of all types, although their interpretation is in all cases problematic.

Social learning

In their natural habitats all four great ape species acquire information in social contexts. The precise social learning mechanisms employed by the different species, however, are not clear. Researchers have identified at least four different types of social learning, requiring different levels and types of social cognition: mimicking (reproduction of sensorimotor acts), local enhancement (fortuitous reproduction due to common attraction to stimuli), emulation (reproduction of changes of state in the environment that others have produced), or imitative learning (reproduction of intentional strategies of others). The social learning of apes has been studied in four domains: arbitrary actions, object manipulations, problem-solving, and communication.

Some wild chimpanzees have been observed anecdotally to reproduce unusual actions of conspecifics such as nut-cracking postures (Boesch, 1992) or scratching postures (Goodall, 1986, 1990) – without any obvious reason for doing so (for a similar observation of a captive chimpanzee, see de Waal, 1982). Some of the human-like behaviors of the rehabilitant orangutans observed by Russon & Galdikas (1993) may also fall into this category. There is some evidence in these cases that the baseline probability of an individual producing the behavior of its own accord is near zero. These types of behavior are also evident in home-raised chimpanzees, for example the human-raised chimpanzee of Temerlin (1975) made vomit attempts after seeing a human vomit. In addition, some studies have trained subjects with various backgrounds to mimic arbitrary actions on command. Hayes & Hayes (1952) found that after extensive training (17 months) a home-raised chimpanzee learned to reproduce novel actions on command. Similarly, Miles (1990) found that the home-raised orangutan also reproduced actions on command after some training. Recently, Custance & Bard (1994) reported mimicking on command after several months of training in two nursery-raised juvenile chimpanzees.

Object manipulation is another domain where imitative learning has been reported.

Spontaneous imitation of numerous household activities such as cleaning, cooking, or dish washing have been reported in many studies of home-raised apes (see e.g. Hayes, 1951). Russon & Galdikas (1993) and Russon (Chapter 7) reported that rehabilitant orangutans – having various background experiences with humans – also displayed imitation of some object manipulations (although there are no baseline measurements of what the subjects would do with the objects naturally). In addition, Mathieu (1982) found that four nursery-raised chimpanzees with some human contact reproduced only a limited number of human activities, and Perinat & Dalmau (1988) and Gómez (1989) reported only a few possible imitative actions on objects by three nursery-raised gorillas one with more extensive human contact. In a study directly comparing the social learning of apes with different experiential backgrounds in this domain, Tomasello *et al.* (1993b) found that home-raised chimpanzees and bonobos displayed imitative learning of actions on objects comparable to that of 2 year old children, whereas chimpanzees and bonobos that had been raised mostly with conspecifics with less human contact reproduced very few of the actions that were modeled by a human demonstrator (almost none of the complex actions).

Numerous studies have investigated the social learning in apes in problem-solving situations. When appropriate experimental controls have been used, no evidence of imitative learning in problem-solving contexts has been found either in chimpanzees or orangutans with limited human contact. For example, Nagell *et al.* (1993) presented captive chimpanzees with a rake-like tool that could be used in either of two ways leading to the same end-result (to control for stimulus enhancement). One group of subjects observed one method of tool use and another group of subjects observed the other method of tool use. It was found that chimpanzees used the same method or methods no matter which demonstration they observed – indicating attention to the change of state in the world observed (emulation learning), not the behavioral means used to effect that change of state (for a similar result with nursery-raised orangutans, see Call & Tomasello, 1994b). In terms of home-raised apes, Hayes & Hayes (1952) found that a home-raised chimpanzee solved a number of problems after observing a human demonstrating the appropriate solution, whereas a chimpanzee with limited human contact failed to solve the problem after observing a human model.

In the domain of communication, there are in the wild some population differences in chimpanzee gestural signaling (Goodall, 1986; McGrew & Tutin, 1978). The best-known of these are "leaf-clipping" (Mahale K (Tanzania) and Bossou (Guinea) communities), and "grooming hand-clasp" (Mahale K, Kibale (Uganda), and Yerkes (captive colony, USA) communities). The basis for these group differences, however, is unknown. In a series of studies of a captive colony, Tomasello and co-workers have studied the acquisition of gestures by infant and juvenile chimpanzees and have found that learning through ontogenetic ritualization (mutual social shaping, as in many prelinguistic gestures of human infants; Tomasello, 1995a) rather than imitative learning was more likely to be responsible for gesture acquisition. Among the pieces of evidence used to make this inference were: there was much individual variability both within and between generations in gestures used, there were a number of gestures used by single individuals,

and shared gestures were the same as those that may be observed in chimpanzee peer groups who have had no exposure to adults. With regard to home-raised apes, on the other hand, Fouts *et al.* (1989) reported that two chimpanzees with extensive human contact acquired some signs by imitative learning (see also Chapter 13), although some studies show that shaping is a more effective procedure for teaching apes sign language (e.g. Fouts, 1972; Sanders, 1985). Also, modeling (in combination with other socialization techniques) has proven effective for teaching home-raised bonobos and chimpanzees to use a communication keyboard (Savage-Rumbaugh *et al.*, 1986, 1992).

In summary, it seems clear that apes raised by humans display much more human-like social learning abilities than apes raised by conspecifics. This is true in all of the domains investigated: arbitrary actions, object manipulations, problem-solving, and communication. It is interesting to note that in the review of Whiten & Ham (1992) in which ape imitative abilities were noted, all of the well-documented examples (with the exception of the several mimicking examples reported here) were from home-raised apes.

Teaching

Another behavior relevant to social learning skills is teaching. A number of researchers report instances of apes in the wild doing things that lead to the learning of others, especially offspring, but it is unclear if this is what the "teacher" intended to accomplish. The classic example is van Lawick-Goodall's (1968) report that chimpanzee mothers "teach" their infants to walk by moving some distance away, turning, and vocalizing to them. Another possibility, however, is that the mother wishes to go somewhere and is simply encouraging the infant to come along. Goodall (1986) also classifies as teaching instances in which a mother chimpanzee takes a poisonous plant away from her infant. But this is just as likely a case of a mother simply preventing her child from doing something dangerous. Recently, Boesch (1991b) reported a number of observations of chimpanzee mothers "teaching" their youngsters a tool use behavior, two of which are possible instances of intentional instruction. In one, the mother slowed down her technique as she cracked nuts (as her youngster watched), and in the other she repositioned the nut into the correct position for cracking after the youngster had been struggling. Although these are very suggestive observations, because there are only two instances and no baseline data for comparison, there are alternative interpretations based on the possibility that the adults are behaving for their own ends (see Tomasello *et al.*, 1993a). Home-raised chimpanzees have not shown strong evidence of teaching skills either. There are only two reported examples of a home-raised ape instructing another. In one a chimpanzee mother demonstrated for her infant a sign-language sign a total of five times (Fouts *et al.*, 1982), and again it is possible her intention was something other than instruction. In the other a gorilla signed to a naive human and when he got no response took her hands, molded the sign, and pushed her to make her move (Patterson & Linden, 1981). Again, whether or not this is intentional instruction is open to debate.

Cooperation

Cooperation in coalitions and alliances for purposes of defense against aggressors and dominance rank acquisition have been extensively documented in wild and captive apes

of all four species (Harcourt & de Waal, 1992). Another domain in which cooperation has been documented in the wild is the hunting behavior of chimpanzees in the Taï forest (Boesch & Boesch, 1989), although this same behavior has not been observed at Mahale (Nishida, 1979) or Gombe (Teleki, 1973). To what degree individuals are actually monitoring the behavior of others and adjusting their own behavior accordingly however, is not entirely clear from the published descriptions. Intentional communication about the cooperative effort was not reported. In some captive colonies chimpanzee individuals have been observed to spontaneously support a pole being used by another chimpanzee to climb into a tree (de Waal, 1982; Menzel, 1972, 1973b), but again it is unclear to what degree there was active coordination and adjustment of the individuals to one another or if there was any intentional communication.

In problem-solving situations, Köhler (1927) reported that chimpanzees with limited human contact engaged more in competition than in cooperation. In the most extensive study to date, Crawford (1937, 1941) studied the development of cooperation in a task requiring a pair of captive juvenile chimpanzees to pull simultaneously on a rope. The pair's initial attempts to jointly operate the apparatus were always uncoordinated, and they succeeded only after human instruction and shaping. Once cooperating, however, one subject actively recruited the other to operate the apparatus. Surprisingly, they did not generalize their skills to a very similar task some time later. More recently, Chalmeau (1994) exposed captive chimpanzees to a similar task and observed some spontaneous coordination of behavior, and there was again some active recruitment of a partner. Also very recently, Povinelli *et al.* (1992) reported cooperation between human–ape pairs (using laboratory-trained chimpanzees) in a task that required one subject in a pair (the informant) to indicate to his or her partner which of four locations contained a piece of food. In turn, the other subject (the operator) had to operate one of four handles so that both subjects could obtain a piece of food. Subjects achieved a level of proficiency in their cooperative efforts without extensive training, and furthermore, when roles were reversed three of the four chimpanzees adjusted to their new roles with little difficulty. Povinelli *et al.* argued that this finding demonstrated that the subjects spontaneously understood the role of the human partner they were cooperating with during the interaction, although it could also be interpreted to mean that they were able to learn their new roles quickly based on what they had learned previously (Tomasello & Call, 1994). Savage-Rumbaugh *et al.*, (1978a) reported that their laboratory-raised chimpanzees were able to collaborate in solving a complex task requiring different roles for each performer; however, this cooperation was not spontaneous because before engaging in this task both subjects were first trained by humans in each of the two collaborative roles.

In summary, ape cooperation has been observed in one form or another in all rearing environments, but the nature of this cooperation is not always clear. Although the evidence of cooperation in the wild is suggestive, the clearest cases of cooperation in which individuals coordinate with one another's roles and actively communicate about this coordination are all from apes with extensive human contact. Even in these cases, however, there are few data on precisely how apes are interacting with one another, and

thus it is not clear whether they are engaging in a human-like form of cooperation with mutual role-taking and intentional communication.

Theory of mind

Many of the just reviewed social skills may be seen as relying on the perception or understanding of the mental states of others. A number of different observations are relevant to this general topic, including the understanding of gaze/attention, intention, and knowledge. Some of these phenomena are very difficult to observe outside experimental situations.

With regard to the understanding of visual gaze or attention, Tomasello *et al.* (1994) found that in a captive colony of chimpanzees visually based gestures (e.g. arm-raise) were performed only when potential recipients were oriented toward the performer; when they were not so oriented, tactilely based (e.g. poke) or auditorily based (e.g. ground-slap) gestures were used. Tanner & Byrne (1993) reported several instances of a captive gorilla hiding her play-face so that others could not see it (see also de Waal, 1982). However, Premack (1988) reported that when captive juvenile chimpanzees needed a human to help open a container, but the human's eyes were covered by a blindfold, only one of the four subjects removed the blindfold from the human. Some similar observations have been made of apes with more extensive human contact. For example, Fernández & Gómez (1983) found that nursery-raised gorillas with a moderate amount of human contact made sure that a human was attending before they performed gestures. In a comparison of two orangutans with different rearing histories, Call & Tomasello (1994) found that a nursery-raised orangutan pointed toward an out-of-reach drink it wanted even when the human's eyes were closed, whereas a home-raised orangutan significantly decreased his frequency of pointing in this situation (as compared with the eyes-open condition).

With regard to the perception of intention, D.J. Povinelli and H.K. Perilloux (unpublished results) presented captive chimpanzees with two scenes: one human spilling juice accidentally and another pouring it out intentionally. When chimpanzees were later asked to choose which of these humans should bring them juice, they showed no preference – presumably indicating an inability to distinguish intentional from accidental behavior when the outcomes were the same. In studying apes with more extensive human contact, Savage-Rumbaugh (1984) reported two anecdotal observations in which a female bonobo refrained from attacking a human that had harmed her infant, presumably because the harm was produced unintentionally. Also in this category, Premack & Woodruff (1978) presented the laboratory-trained, language-trained chimpanzee Sarah with pictures of humans in problem-solving situations (e.g. an out-of-reach banana). Among several alternative pictures presented as solutions, Sarah quite often correctly chose the one that represented an appropriate solution. It should be noted, however, that Sarah may have been choosing solutions on the basis of some criterion other than the attribution of intentions (for this argument, see Savage-Rumbaugh *et al.*, 1978b), and that Premack (1986) briefly reported on the failure to train Sarah to discriminate between other picture sequences that depicted intentional and nonintentional actions. Tomasello *et al.* (1993b) argued that the imitative learning of the behavioral strategies of others by home-raised apes demonstrated their ability, in contrast to captive apes, to perceive the intentions of others.

Finally, with regard to the attribution of knowledge to others, Premack (1988) reported negative results of a false belief task for laboratory-raised Sarah. In this experiment, Sarah did not modify her behavior to take account of a difference in knowledge states between herself and a human experimenter. Premack (1988) also reported a study in which one human baited one of two boxes in the presence of another human that had visual access to the box that was being baited. Four juvenile chimpanzees (captive, with unreported experiential histories) observed this process but were kept ignorant about which container was being baited. Another human remained outside the room and consequently did not know which container was being baited. After this naive human entered the room, subjects could choose between the naive and the knowledgeable human. After they had chosen, the human pointed to one of the containers, and subjects made their choices. Results indicated that two of the four chimpanzees came to correctly choose the experimenter who knew the food's location. Povinelli *et al.* (1990) reported similar results, and in addition found that chimpanzees learned to generalize to a situation in which a human covered his head while the apparatus was being baited. They did not generalize to this situation immediately (Povinelli, 1994a), however, and it is thus possible that, in both the Premack and Povinelli *et al.* experiments, what subjects were doing was learning to respond to specific discriminative cues. Support for this view is the recent failure to replicate these findings with nursery-raised juvenile chimpanzees (Povinelli *et al.*, 1994).

In summary, all apes seem to have some knowledge that visual gaze or attention is important for some interactions. Only apes with more extensive human contact, however, have demonstrated that they understand others in terms of their intentions – although the evidence in this domain is far from perfect. The evidence for an effect of extent of human contact on apes ability to infer the knowledge states of others is mixed, and indeed there is some question at this point of whether apes infer knowledge states at all (Povinelli, 1994b).

MECHANISMS OF HUMAN INFLUENCE

Looking across all of these domains of ape cognitive development, several patterns may be discerned (see Table 17.3). With regard to physical cognition, it may be said that after a few years of age apes of all four species, no matter how they are raised, have a sense of the permanence of objects that would seem to be very similar to that of human infants from the middle of their second year of life. When it comes to the specific properties of particular objects, however, it seems that different individuals know more or less depending on their exposure to them: apes who have been exposed to a wider range of objects and tools during early development know more things to do with them in terms of object manipulation, tool use, mirror use, and categorization. In addition, if individual apes are trained to do so they can learn to sort objects into groups on the basis of

Table 17.3. *Summary of the effects of humans on the development of apes in different cognitive domains*

Domain	Effect of interaction with humans
Object permanence	Interaction with humans not necessary
Object manipulation, tool use, mirror use, symbolic play	*Exposure* to human artifacts and *emulation* of their use leads to quantitative increases in knowledge of objects and their properties and dynamic affordances. May occur in many types of captive environments
Categorization/classification, quantitative skills	Interaction with humans not necessary for natural categorization, but some *training* may be necessary for explicit classification and quantification based on abstract properties (e.g. training in attention management skills). Typically occurs in laboratory environments
Social attention, social referencing, understanding visual gaze	Interaction with humans not necessary
Intentional communication, imitative learning, understanding intentions	Being *enculturated* by humans may lead to an understanding of others as intentional and thus to qualitatively more human-like skills of social learning and intentional communication. Typically occurs only in home-raised environments
Cooperation, teaching, understanding beliefs	Human interaction has no significant effect because human-like skills in these domains may not be attainable by apes of any kind

relatively abstract perceptual dimensions and to make judgements based on numerical quantity.

We see three possible mechanisms of these effects. First, it is possible that simple exposure to many and varied objects during ontogeny is sufficient for apes to learn many of their interesting properties, and perhaps to develop some generalized skills for exploring new objects. But secondly, it is also likely that much of ape learning about objects in human environments occurs when they observe humans manipulate and use these objects, and they learn some particular affordances of particular objects that they would not have discovered on their own. This is what we have previously called emulation learning: by observing the object manipulations of others an individual learns about changes of states in the environment that may potentially be brought about (Tomasello, 1990). This same effect is most likely what accounts for the few anecdotal

observations of symbolic play in home-raised apes as well. Thirdly and finally, specific training with particular kinds of material may lead apes to attend to certain abstract properties of objects, including dimensions on which they may be classified or quantified. We thus believe that together these three mechanisms of human influence – exposure, emulation, and training – lead apes to learn much more about objects and their properties than they could possibly learn if left totally to their own devices. We do not believe, however, that such exposure has any fundamental, qualitative effect on apes' understanding of the physical world. The effect is merely quantitative in the sense that the effective variable is the amount of exposure that different individuals have had to objects and their affordances, and the outcome is learning more about the types of thing that all apes are capable of learning about.

In the social domain, the picture is more complex. Apes of all four species, however they are raised, show a basic level of social attention in the sense that they are attached to and attend to their mothers, siblings, peers, and other conspecifics. Interaction with humans is not needed for the development of these behaviors. It is also very likely that all types of ape follow the gaze of others to outside entities and use their reactions as a guide as to how they should interact with the entity, mostly in situations of emotional arousal. Again, interaction with humans is not needed for the development of these skills. At the other end of the spectrum are sociocognitive skills that humans also do not influence, but in this case it is because apes are not capable of those skills under any circumstances. Thus, we do not believe that the evidence supports the view that apes of any type understand the mental states of others in terms of their beliefs, and we do not believe that apes of any type engage in the most human-like forms of cooperation and teaching (which may rely on an understanding of the beliefs of others). Thus interaction with humans does not seem to play a role in these domains either, but for different reasons.

The sociocognitive domains in which humans seem to have the greatest effect on apes are intentional communication and social learning. Thus, referential pointing and more elaborate forms of imperative communication in general (and possibly the use of declarative forms of communication), not to mention the comprehension and use of linguistic symbols, have been observed only in home-raised apes. Similarly, the most clearly demonstrated cases of imitative learning, in a number of different behavioral domains, are all from apes who have interacted extensively with humans. Why this should be the case is not known at this time. It is possible, however, that these effects result from home-raised apes acquiring a deeper understanding of others in terms of their intentions, i.e. in terms of the means–ends structure of their behavior (Tomasello, 1995b).

Intentional behavior may be understood at different levels, and so to be more precise about ape understanding of intentions, and how humans might influence this understanding, we must look more closely at intentionality. First of all, it is clear that all apes understand something about the directedness of behavior. A mother ape watching her youngster come toward her and pull at her arm in some sense knows that it is coming to nurse, and an adult ape can tell when another adult is getting ready to mate or attack. These things are understood because they are behavioral sequences with which the mother or adult is familiar from past experience; they understand that specific acts lead

to specific results with a high degree of predictability. This is the simplest level of the understanding of intentionality. At the other end of the spectrum, there is the understanding of intentional behavior that relies on the distinction between intentional and accidental actions. There is no good evidence that apes of any type understand this distinction, and in fact some evidence that they do not (D.J. Povinelli & H.K. Perilloux, unpublished results). The reason for this failure may be that in many accidents and intentional actions the outcome is the same, and apes may be predisposed to understand as similar all actions that result in the same outcome.

But there is a middle level in which the understanding of intentions goes beyond the understanding of simple directedness, or even a more generalized understanding of what an individual is likely to do next in a behavioral sequence, but still stopping short of distinguishing intentional and accidental actions that have the same result. This middle level involves the understanding of behavior as intentional in the sense of differentiating means from ends. This distinction relies on an understanding of such things as that there are multiple means to the same end, that obstacles may be overcome by intermediate means, that the same behavior may be either a means or an end in appropriate circumstances, and that others have ends (intentions) that may not match one's own (Piaget, 1952; Tomasello, 1995b).

In this case we think there is evidence for different skills in apes as a function of human contact, and this evidence consists precisely of behavior in the domains of intentional communication and social learning. Thus, in the wild, there is no evidence that apes point to outside entities for one another, nor do they imitatively learn new instrumental behaviors from one another. Our hypothesis is that they do not do these things because they do not understand that others have independent intentions and attention that differ from their own that they can follow into or direct or reproduce. Apes raised by humans, however, often do develop such skills. They point to things for others (and may use linguistic symbols), create relatively elaborate new means of imperative communication with others, and they imitatively learn new skills from others, reproducing both means and ends in the process. The hypothesis is that individuals can learn to do these things when they come to understand that others have intentions and attention that differ from their own and that may be achieved by different alternative means.

The question thus arises as to how human interaction may lead apes to an understanding of others as intentional. Our hypothesis is that, to understand others as intentional, individuals must be raised in cultural environments in which they themselves are treated as intentional by others (Kaye, 1982), perhaps from a very early age. Thus, adult human beings attempt to make their children, and sometimes apes, look at things and do things. When the children and apes do so, the adults reward them for doing so. In their interactions with children and apes, human enculturators thus structure and encourage triadic interactions (involving adult, child/ape, and outside object) in a way that adult chimpanzees in their natural environments do not do for their young. It is possible that during the enculturation of apes this "scaffolding" and intentional instruction serves to "socialize the attention" of the ape in much the same way that human children have their attention socialized by adults (Vygotsky, 1978). This process makes possible all kinds of triadic interactions involving the "referential triangle," including various forms of cultural learning and related sociocognitive skills (Tomasello *et al.*, 1993a). In terms of motivation, it is also important to note that human environments make many desirable objects inaccessible to apes, and because humans control access apes learn to use their triadic skills to help them in gaining control over the material and the social environment they inhabit (Savage-Rumbaugh, 1990).

It is important to remain aware of the fact that being treated intentionally does not turn apes into humans. There are two main differences in our view. The first concerns social and communicative motivation (Gómez *et al.*, 1993; Savage-Rumbaugh *et al.*, 1983; Terrace *et al.*, 1979). Home-raised apes learn to use imperatives to request behaviors of others, and they show very human-like skills of imperative pointing and other forms of requesting. The use of declaratives is rare in apes, however, and moreover, the purported declaratives of apes differ from human declaratives in some important ways. What have been identified as ape declaratives all occur either in noncommunicative contexts (e.g. self-signing) or else in communicative contexts in which the ape is calling attention to a specific object or person for purposes of spurring a desired action, e.g. by pointing out an object with which an action is desired. In contrast, when human infants use declaratives the goal is simply to share attention with someone to something. No apes, not even home-raised apes, seem to enjoy showing objects to others simply in order to point out to them some interesting feature or features.

The implications of this motivational difference between apes and humans are enormous. Motivational differences may not only explain the paucity of declaratives in the intentional communication of home-raised apes, but it also may be responsible for the differences found between humans and apes in other domains such as joint attention, imitation, teaching, and cooperation. Although in human ontogeny each of these abilities follows its own developmental course and timing, it is still possible that they each have (at least in some contexts) the same "purely social" motivational component, i.e. to share attention, knowledge, or skills, simply for the sake of sharing them. The possibility is thus that home-raised apes learn some triadic skills through the process of being treated intentionally, but they apply these skills in imperative contexts only – because this is the nature of their species-specific motivational structure. This motivational structure may not be subject to serious modification.

The second important difference between humans and home-raised apes is that home-raised apes do not create cultural environments for one another. Even though they respond in interesting ways to a human cultural environment, as we have shown in this chapter, it is quite another thing to create such an environment. Despite one anecdotal observation of one home-raised ape teaching another (Fouts *et al.*, 1982) it is doubtful in our view whether if all home-raised apes were suddenly placed in a single group and left to their own devices, they would create cultural environments of the human kind. The problem may be cognitive since certain forms of intentional instruction depend on being able to understand others in terms of their beliefs (Cheney & Seyfarth, 1990; Tomasello *et al.*, 1993a), and we have argued previously in this chapter that apes, whatever their upbringing, do not conceive of others in terms of their beliefs. Or it may

be motivational, as we have just argued: adult apes are not motivated to instruct or share knowledge with their young because it has no immediate consequences for themselves.

Our hypothesis is thus that being treated intentionally by others, i.e. being enculturated into a cognitive community, is an integral part of the ontogeny of certain sociocognitive abilities, especially the ability to understand behavior intentionally. It may be especially important to have such experiences early in development. This then leads to a number of specific ways in which apes behave with humans and conspecifics after they have come to understand behavior in this way, mostly involving access to the referential triangle in which the intentions of the two participants are mutually understood. There are still important differences between humans and apes, however they are raised, and we have speculated that these involve the use of the referential triangle for purely social motives and the ability to create cultural environments for others.

CONCLUSION

The cognitive development of apes is affected by contact with humans. We have outlined four mechanisms that may be responsible. First, apes learn new things about objects and their properties and relationships by simple *exposure* to them, and, in the case of tools, the need to use them. When apes are raised by humans, even in simple captivity, they are typically exposed to more different types of object and artifacts crafted for specific uses than when they grow up in their species-typical environments. Secondly, apes engage in *emulation learning* about objects: when they see an object being manipulated or used they learn something about that object's affordances or relations to other objects that they might not have discovered on the basis of their own explorations. Again, when apes are raised with humans – in some captive and many nursery environments, for example – they very likely observe more of these kinds of object manipulations. Thirdly, apes may learn some specific skills through explicit *training* in which humans, typically in laboratory settings, assist them in identifying what to pay attention to and what to do in solving particular cognitive tasks such as the categorization of objects on the basis of abstract features. Fourthly and finally, we have hypothesized that the experience of being treated intentionally by others in home-raised environments, what we have called in other places *enculturation* (Tomasello *et al.*, 1993a), may lead to a fundamental change in the social cognition of apes such that they begin to differentiate between means and ends in the behavior of others and thus view these others as intentional agents. This leads to a whole host of changes in other (though not all) areas of socio-cognitive development, especially in the domains of intentional communication and social learning.

It is important to emphasize that the conclusions we have reached in this review are limited in a number of ways. First, much of the information reported in several domains is based almost exclusively on anecdotal accounts, and this is especially true of home-raised apes. Although we do not reject anecdotes as potentially valuable information, anecdotes alone are insufficient for drawing firm conclusions: "The plural of anecdote is not data" (Bernstein, 1988). Secondly, the seeming sophistication found in home-raised subjects

in several domains such as teaching or symbolic play may be a result of the fact that they are observed for a greater amount of time and in more human-like environments than are other apes; consequently, interesting behaviors are much more likely to be observed, perhaps especially for behaviors of low frequency such as teaching or symbolic play. Thirdly, there are some variables such as age or age of exposure to certain rearing conditions that make it difficult to reach definitive conclusions about the role of humans in certain domains, not to mention the fact that the rearing histories of many individuals are not reported in enough detail to reconstruct what precisely were their experiences with humans.

Nevertheless, we still believe that we have uncovered some patterns of difference between apes raised in different environments, and that these deserve future research attention. We also believe that there are two rather immediate consequences of our review that are vitally important to current thinking about ape cognitive development. The first is that the supposedly fundamental differences in various aspects of the cognitive development of monkeys and apes may not be as great as many scientists have claimed (e.g. Povinelli *et al.*, 1992; Whiten & Ham, 1992). Many monkey–ape differences in cognition may result from the fact that the apes producing unique behaviors or skills have been raised in human-like cultural or laboratory environments of a type that monkeys have not been systematically raised or studied in (Tomasello & Call, 1994). We thus do not know what enculturated monkeys would do in some of the cognitive tasks at which home-raised apes are so proficient. This question awaits future research.

The second consequence of our review is a highlighting of the need for a truly developmental perspective. Whereas some researchers might argue that attributing a cognitive capacity to a species is appropriate if at least one subject, whatever its ontogenetic history, is able to display the requisite skills, we believe that this argument basically trivializes the whole notion of ontogeny and the ontogenetic environment. Organisms inherit their species-typical environments as much as they inherit their genomes, and for many species the species-typical ontogenetic sequence depends in fundamental ways on that environment (Schneirla, 1966). If individuals of the same species end up with one set of skills in one environment and another set of skills in another environment, we may say that the species has two sets of capacities, but it is more informative to say that in one ontogenetic environment one set of skills emerges and in another ontogenetic environment another set of skills emerges. In the particular case of interest here, we would simply argue that when great apes spend their early ontogenies in something resembling a human cultural environment, rather than in their species-typical environments, some of their cognitive skills develop in more human-like ways. We cannot ignore the active role of the environment, especially the social environment, in the cognitive development of primates.

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